A measurement of the radiation field in the CDF tracking volume

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for the CDF radiation monitoring group

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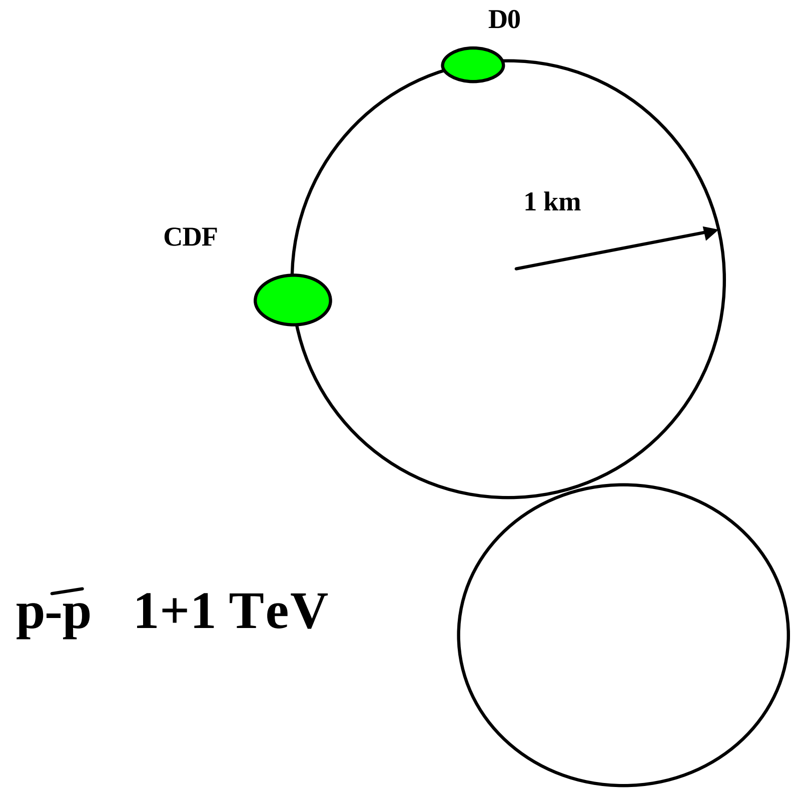


Introduction

- Why to measure the radiation field:
  - **Predict accurately the lifetime of the present silicon tracker,**
  - **Correlate with beam parameters,**
  - **Refine models for run-IIb at Tevatron and for the future colliders.**

- How do we measure radiation:
  - **Beam shower counters (scintillators)**
  - **Beam Loss Monitor (ionization chambers)**
  - **Thermo Luminescence Dosimeters**
  - **Silicon diodes**
  - **Current increase in the silicon tracker.**

The CDF Tracker

CDF general structure

- Silicon vertex Layer (Layer-00)

  single-sided silicon strips: 6 z-segments, 12 wedges
- Silicon Vertex Detector (SVX)

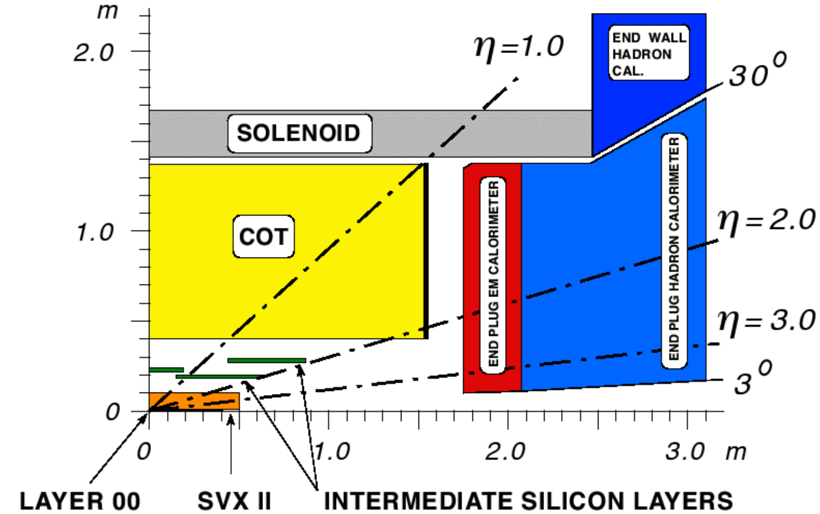
  double-sided silicon strips:

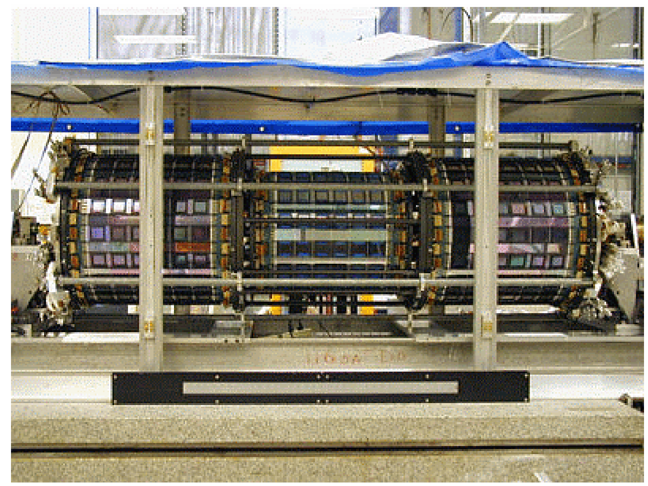
  6 z-segments, 12 wedges, 5 layers/wedge
- Intermediate Silicon Layers (ISL)

  double-sided silicon strips
- Central Outer Chamber (COT)
- Solenoid
- Calorimeter
- Muon Drift Chambers

Silicon tracker:

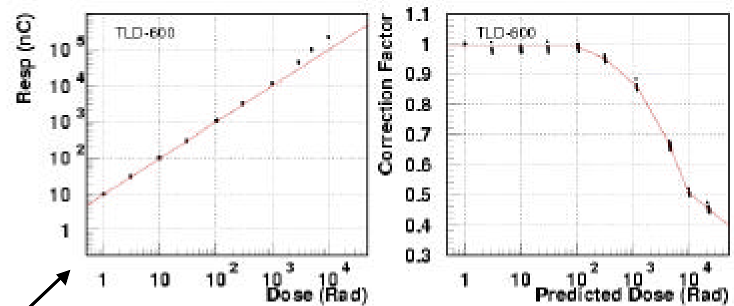
722500 strips, 5644 chips, 5.8 m^2 of silicon in a 35-liters volume ($\varnothing$ 56 cm $\times$ 2m)

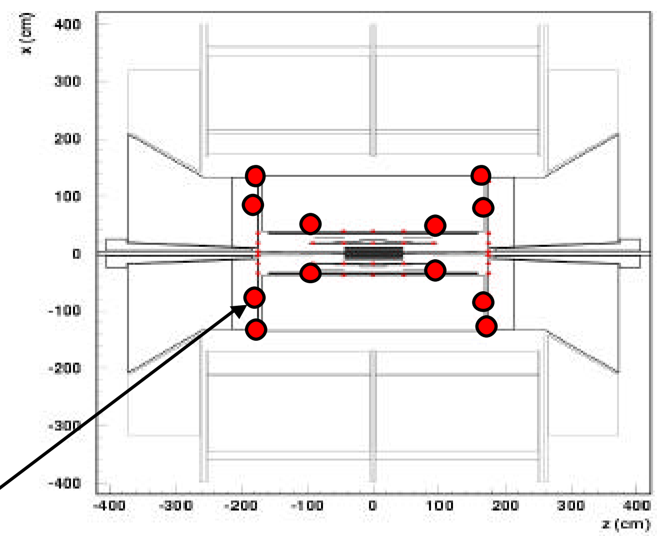




Method 1: TLDs

- Thermo Luminescence Dosimeters (same as used in personal badges)
- + Industry standard
- + Large dynamic range up to 200 kRad
- + Passive (no in situ readout or power needed)
- - Requires harvesting and handling
- + Extremely good accuracy after calibration (1 Rad exposure ^{137}Cs):
  - **1% reproducibility**
  - **Non linearity was measured**
  - **Chip to chip variation: 3%**





2 types of dosimeters used:
g :sensitive and g,n sensitive. 3 chips per type per holder, 145 holders placed in the tracking volume.

Method 2: Silicon current

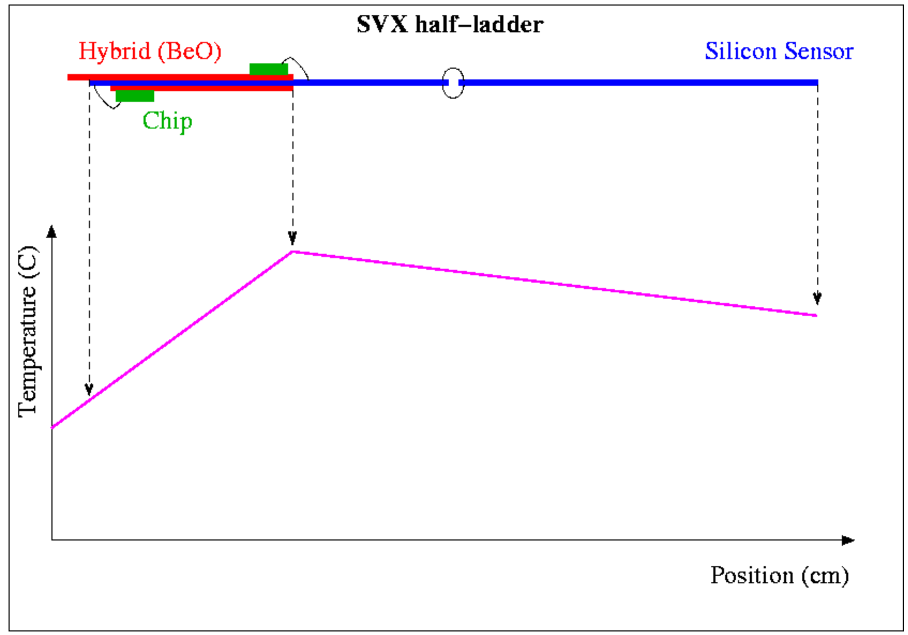
- After irradiation, silicon “reverse” current is typically dominated by defect-induced generation current. Very well studied volume effect:

  D**I(T)** = a **(T)** F **Vol**

  a = **damage constant**

  F = **Fluence (integrated flux)**

- α does not depend on Silicon material and dopant: we use $\alpha = 3.0 \times 10^{-17}$ A cm at 20 C.
- → If generation current dominates the increase of current in silicon detectors can be used as a dosimeter.
  - **Dynamical range: 10^{10} to 10^{14}cm^{-2}**
  - **Continuous reading, no handling**
  - **Readout and recording in detector controls: readout every 10 s.**
  - **Sensitivity: we have 10 nA resolution on 4 out of 8 layers (L-00, SVX L0, L1 and L3)**
  - **Fills the entire tracking volume (no extrapolation)**
  - **Main difficulty: temperature and other systematic effects**

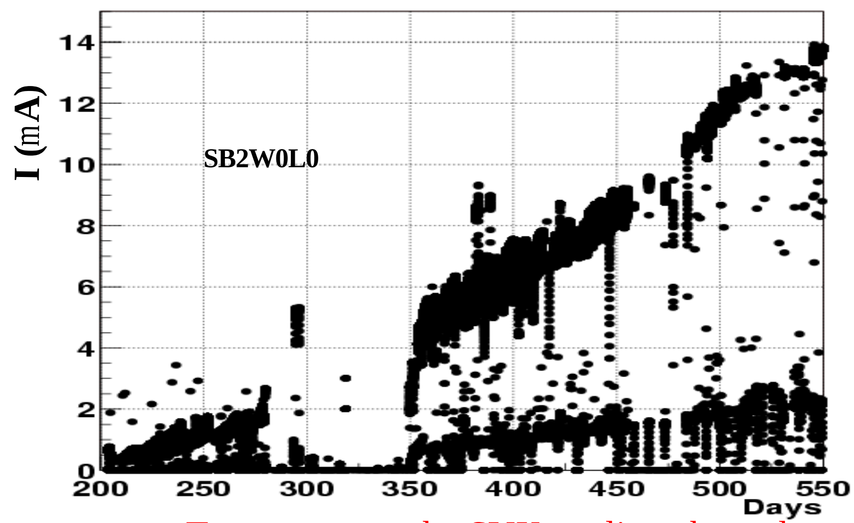


Temperature is not uniform in SVX ladders
Piecewise linear temperature model is needed to calculate current at 20 C.
Layer-00 is more reliable because electronics is separated from sensor, so the temperature is uniform.
Also, L-00 is single-sided strip detector

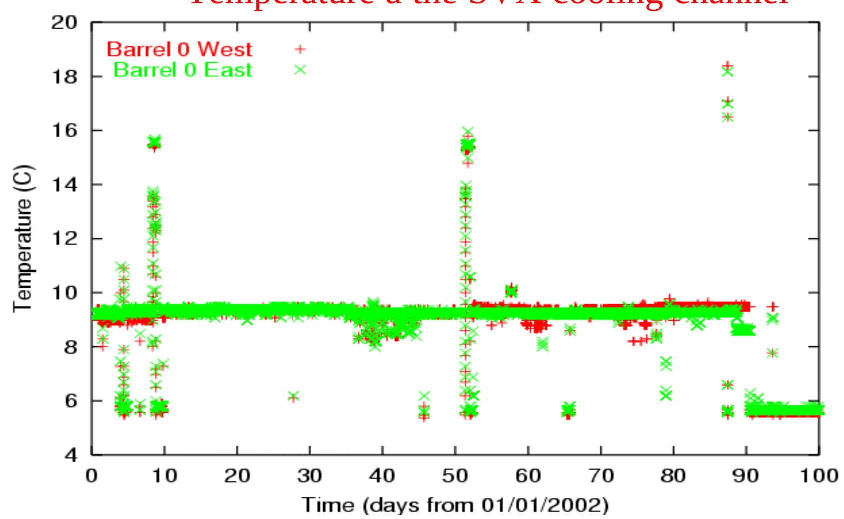
Method 2: Silicon current

- Measure the temperature and the current
- Apply the temperature corrections
- Average currents per "beam store" on each detector element. Find the correspondent delivered luminosity
- Perform linear fit
- *Clean-up from ladders with dubious behaviour and "stores" with known anomalies*
- Data analysis (Fluence vs. φ, z, R)

Raw data: Silicon currents



Temperature a the SVX cooling channel

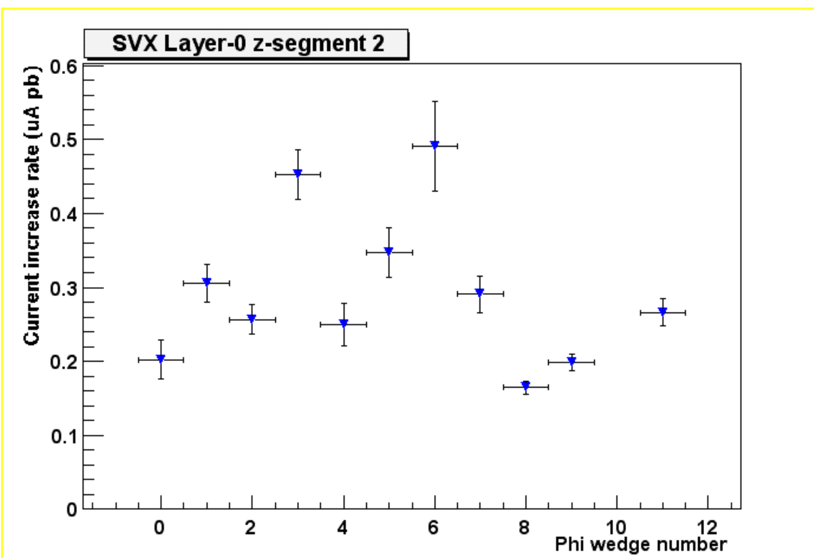


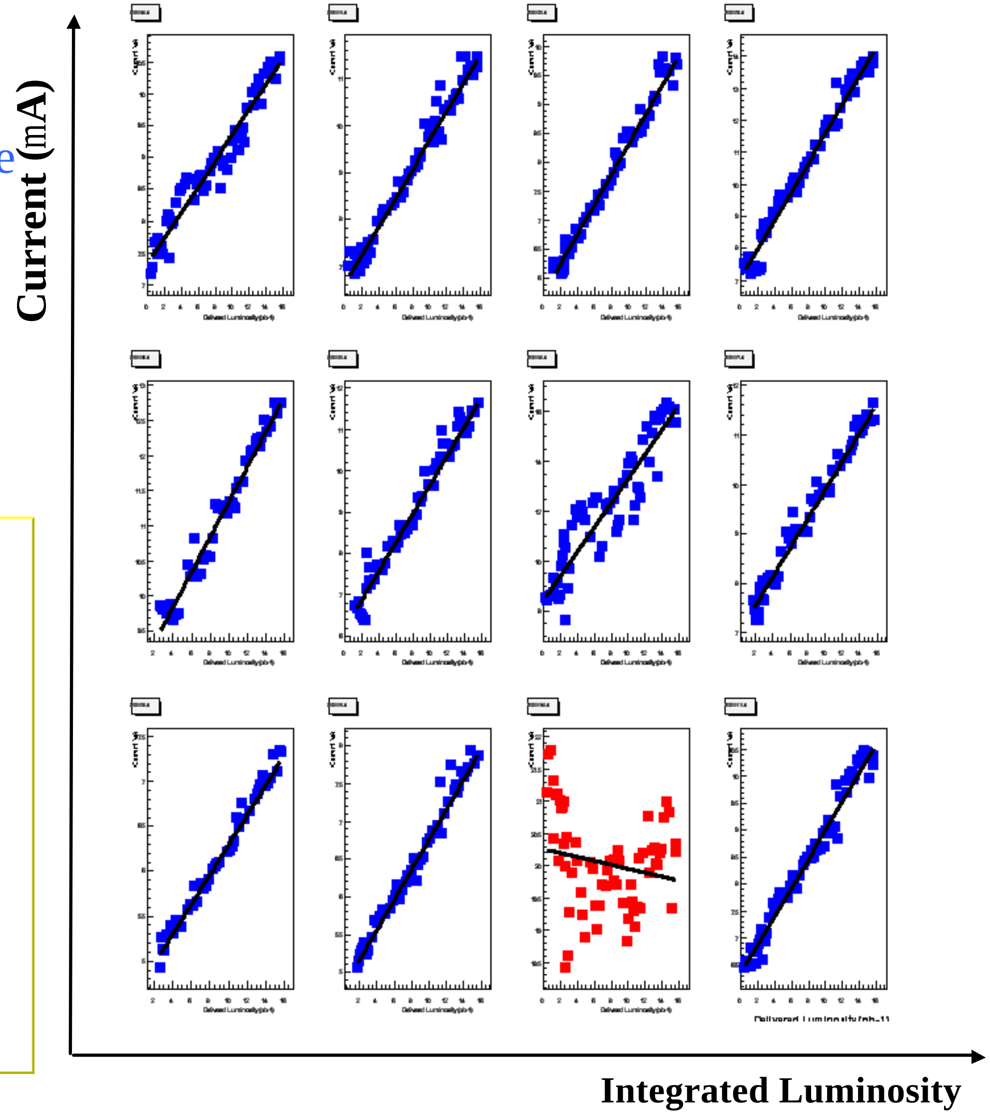
Note: Temperature was recently decreased to nominal operating temp (-6 C).

From currents to fluence

- Linear fit of current vs. integrated luminosity, for each detector element.
- Slope is proportional to the fluence rate (particles/cm^2/pb^{-1}):

  Fluence Rate = slope / ($\alpha \cdot$Volume)
- Plot the fluence rate vs polar angle φ: effects due to off-centre beam.

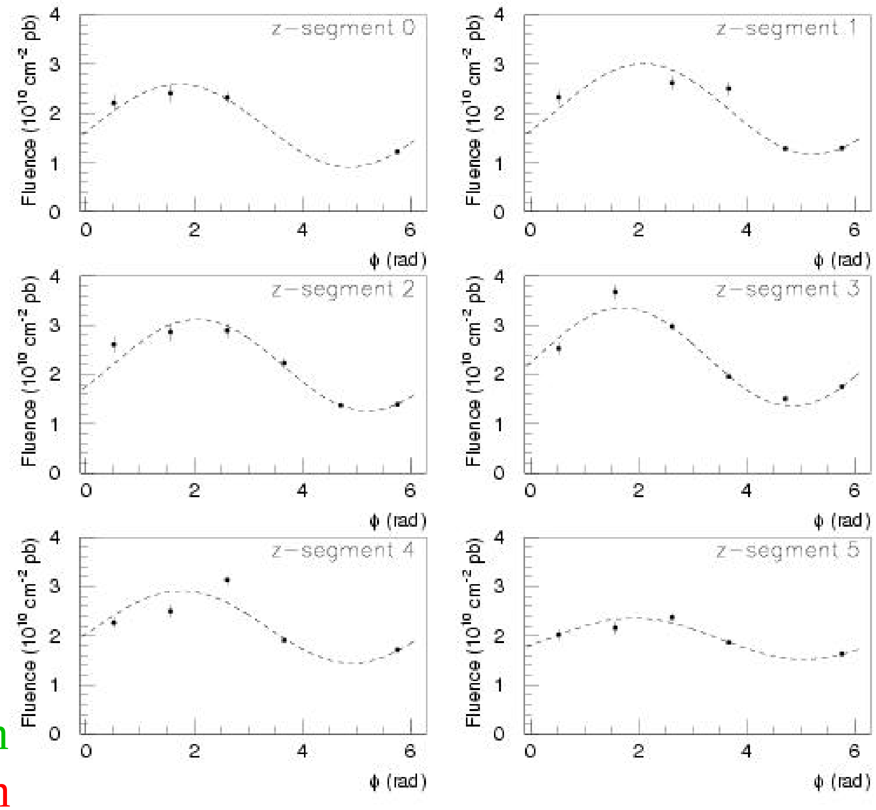




Results: Silicon Currents

- Plot fluence vs φ, fit with sinusoidal.
- Amplitude → distance beam - axis
- Phase → beam position
- Offset→ average fluence

Z	φ_0 (rad)	Amplitude (cm^{-2}/pb^{-1})	Offset (cm^{-2}/pb^{-1})	χ^2	df
0	1.73±0.16	0.84±0.12	1.75 ±0.06	1.9	3
1	2.09 ±0.03	0.92 ±0.07	2.08 ±0.06	7.1	4
2	2.06 ±0.03	0.92 ±0.06	2.18 ±0.05	2.2	5
3	1.69 ±0.02	1.00 ±0.05	2.35 ±0.03	3.8	5
4	1.77 ±0.04	0.73 ±0.05	2.17 ±0.03	19.0	5
5	1.91 ±0.06	0.42 ±0.05	1.94 ±0.03	1.9	5



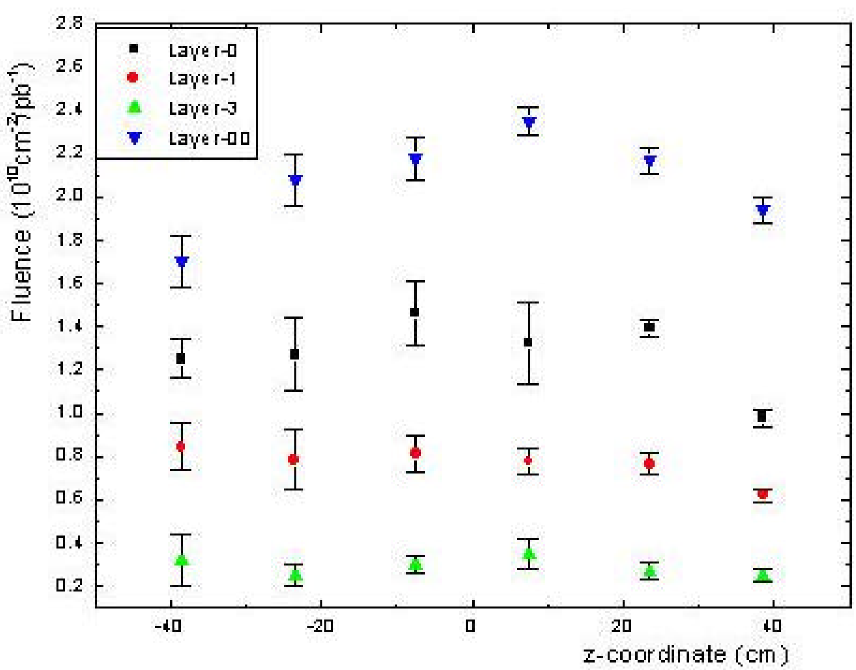
Tracking finds: φ_0 = 1.813, Displacement = 3.1 mm

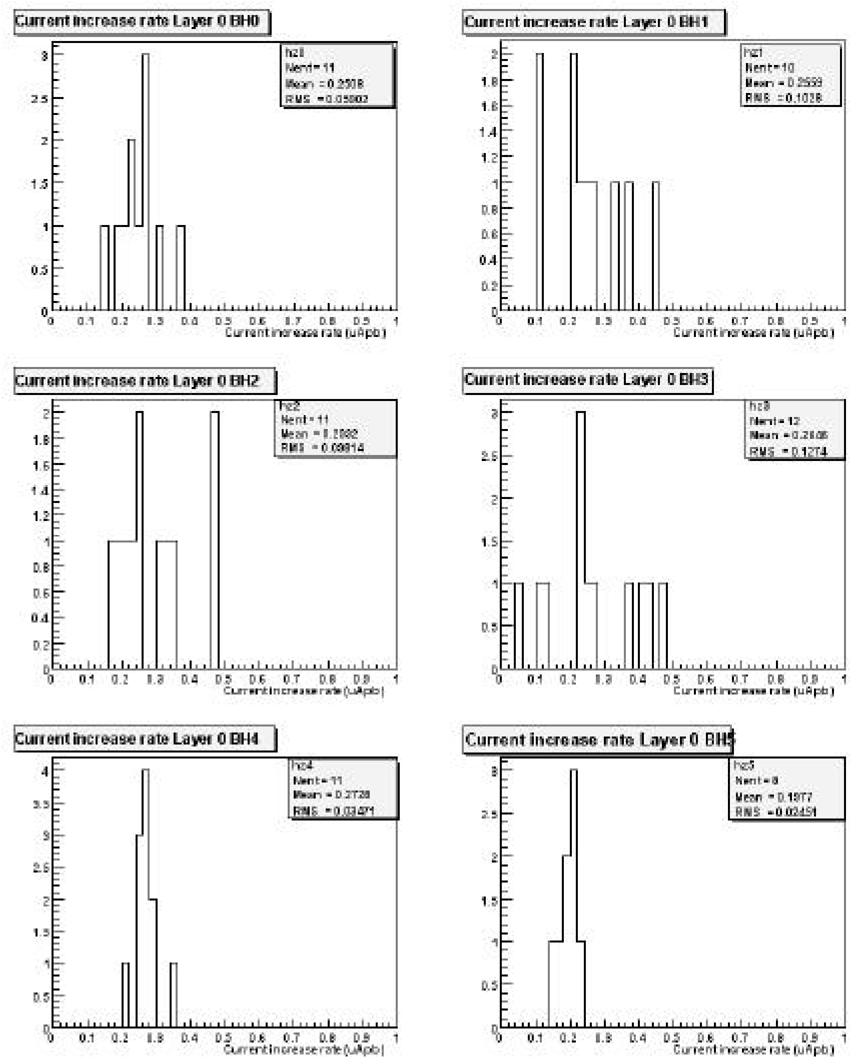
Silicon currents: φ_0 = 1.88, Displacement = 4.8 mm

Current Measurements:
z-dependence

- Z-dependence:

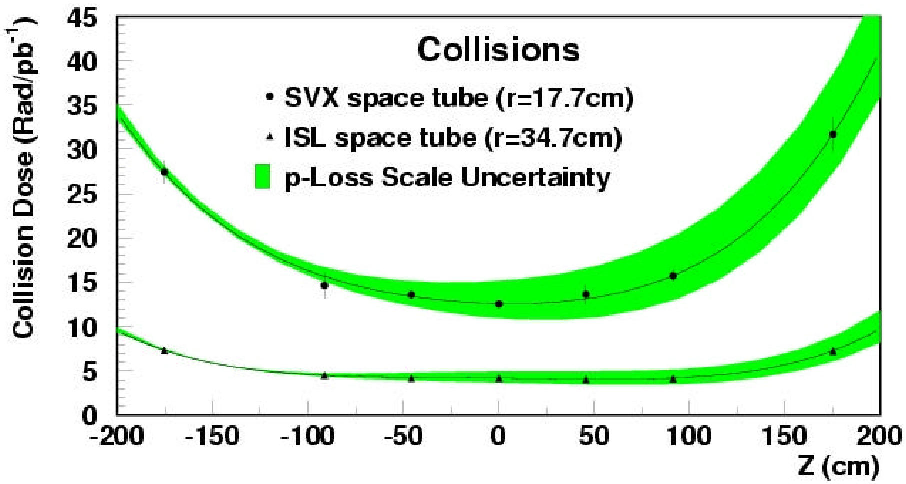
  SVX: use φ-averaged fluence value per z-segment and RMS as error.
- L-00 use fit parameters.
- Overall agreement with TLD measurements, details to be understood

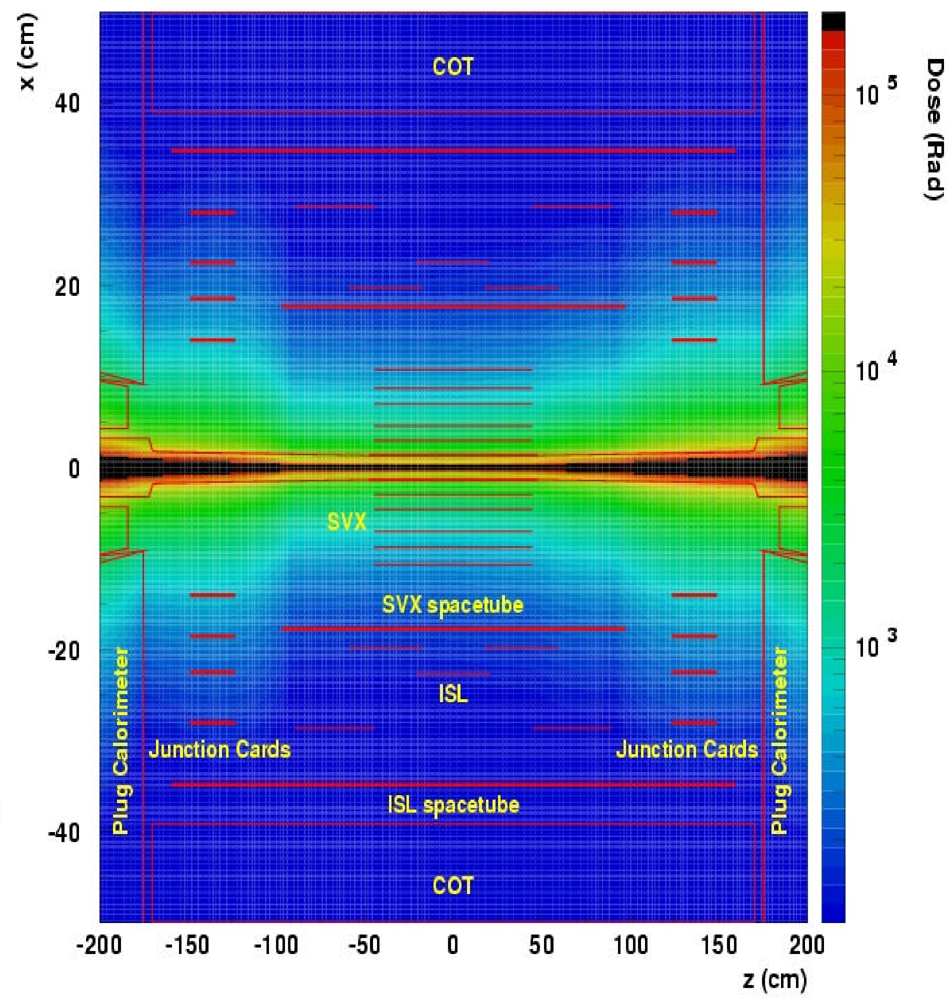




TLD results

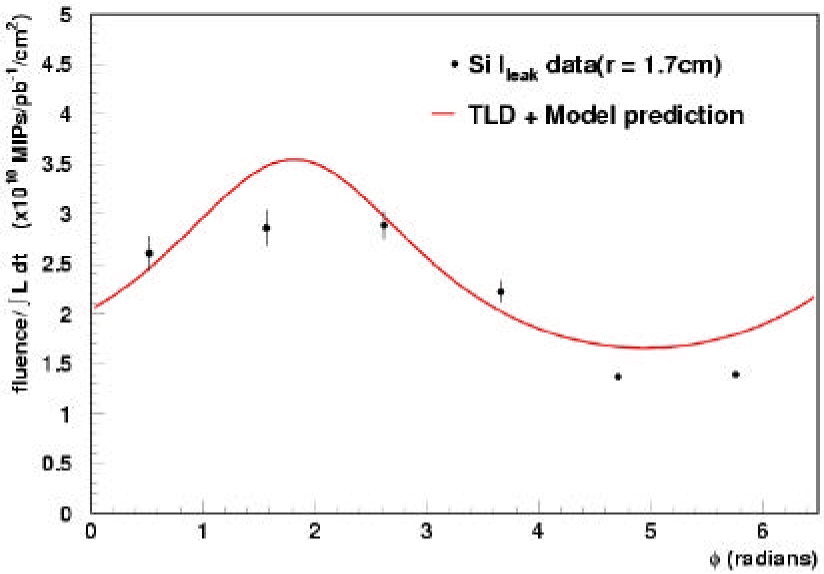
- Separated contribution of beam losses from collisions using luminosity monitor and Beam Loss Monitor.
- Mapping of radiation field was possible interpolating points and assuming power law in R (distance from the beam line).





Comparison of methods

- Converting radiation dose to fluence with $3.87 \cdot 10^7$ MIP/rad and extrapolating the dosimeter measurements to 1.66 cm radius (L-00) we have an **average deviation of 10%.**
- At present the dependence on radial distance is 35% different with the two methods. Systematic effects due to ladder to ladder temperature variation or related to the beam (losses, occupancy..) will be included as soon as we have possibility to disentangle these effects.



Conclusions

- Accurate measurement of the radiation field has been performed with small dosimeters.
- This measurement was complemented by reverse current measurements in Silicon detector, although with larger systematic effects.
- Dose rate from silicon current is in agreement with what expected: **$1.30 \cdot 10^{10}$ cm^{-2}/pb^{-1} at SVX L0.**
- The results from the two methods are in good agreement, they will be merged, once we understand better the systematic effects.
- **The radial dependence is less steep than expected.**
- **We may need to move the silicon detector to make it coaxial with the beam.**

Conclusions

Suggestion for future Si detectors:

- Local temperature measurements are vital for high precision current monitoring
- Produce very accurate thermal model of modules.
- Use high sensitivity, well calibrated nA-meter in power supply, if possible.
- Use TLD in commissioning stage
- Use reference diodes and temperature probes to be read-out for radiation measurements

Work in progress:

- Analysis of reference diode data,
- Investigation of systematic effects in current monitoring:
  - **Temperature variations**
  - **Temperature inhomogeneities**
- Calibration of TLD at very high dose.
- Extend the study to layers equipped with low sensitivity nA-meters.